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Tracking major endocrine disruptors in coastal waters using an integrative approach coupling field-based study and hydrodynamic modeling☆

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ABSTRACT

Many of the world's large coastal cities discharge partially treated wastewater effluents containing various endocrine disrupting chemicals (EDCs) to coastal environments. Nonylphenols (NP) and bisphenol A (BPA) were found to be the most abundant EDCs in sewage effluents in Hong Kong. The environmental fate and ecological risk of these two EDCs remains largely unknown, particular for coastal systems with complex hydrodynamic flows. Based on a validated three-dimensional (3D) multiple-scale hydrodynamic model, a field-based study was conducted to track the two EDCs from potential sources to the only marine reserve in Hong Kong. The two compounds were detected in all seawater, suspended particle, and sediment samples, with higher aqueous concentrations in wet season than in dry season. High concentrations in sediments suggest sediment is a sink, posing an ecological risk to the benthos. The fate and transport of the two EDCs was predicted using a 3D near-field Lagrangian jet model seamlessly coupled with a 3D shallow water circulation model. The results suggested the NP and BPA in the marine reserve cannot be solely attributed to the nearby submarine sewage outfall, but likely concurrently contributed by other sources. This study calls for more effective measures of reducing the use and release of these EDCs, and research to investigate their impacts on the marine benthos.

1. Introduction

Endocrine disrupting chemicals (EDCs) are ubiquitous in coastal marine environments of urbanized coastal cities like Hong Kong (Kueh and Lam, 2008). We previously found that two common EDCs, namely nonylphenols (NP) and bisphenol A (BPA), exhibited elevated concentrations in seawater samples collected across the marine environment of Hong Kong (Xu et al., 2014, 2016). The two compounds have been identified as major anthropogenic contributors to endocrine-disrupting activities in aquatic environments worldwide (Auriol et al., 2006). Nonylphenols are the main degradation products of alkylphenol polyethoxylates, which have been used widely as surfactants in household detergents, agriculture and textile industry (White et al., 1994). NP can cause an increase of vitellogenin and a decrease in the growth rate of testes in male rainbow trout, and disturb the estrogen receptor (ER) pathway in juvenile Atlantic salmon at low environmental concentrations (White et al., 1994; Bonefeld-Jørgensen et al., 2007). BPA is an industrial raw material mainly used in plastic, rubber, adhesive, and cable industries, and is known to cause a delay in the hatching of eggs and a suppression of growth in juvenile rainbow trout (Aluru et al., 2010), and decrease their sperm production at 20 ng/g (Von Saal et al., 1998). It has been widely recognized that effluent discharges from sewage treatment plants (STPs) are the major source of the EDCs being released into aquatic environments, including rivers, estuaries and coastal marine waters (Niven et al., 2001; Zhang and Zhou, 2008; Grover et al., 2011). Submarine outfalls are commonly used for disposal of partially treated effluents from STPs in urbanized coastal cities, like Hong Kong. These

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partially treated sewage discharges are typically located in relatively shallow waters (5–20 m depth), and often close to sensitive receivers such as bathing beaches, fishing grounds and marine protected areas (MPAs) (Choi et al., 2009; Xu et al., 2015a, 2016). Twelve phenolic EDCs have been detected in treated effluents discharged from the STPs in Hong Kong, which may pose risk to marine organisms inhabiting in the receiving water body, including those living in the Cape D' Aguilar Marine Reserve (CAMR), which is situated on the southeastern tip of Hong Kong Island (Fig. 1) (Xu et al., 2014, 2015b).

In 1995, the Hong Kong government, recognizing the importance and urgency of protecting the environment of Cape D' Aguilar, designated this area as the first and only marine reserve in Hong Kong. The CAMR has a rich marine biodiversity, with numerous inhabitants such as fishes, corals, and marine invertebrates (Morton, 1995). This reserve is considered to be of immense scientific and environmental significance, and is managed as a single ecological unit under special protection by Hong Kong legislation (i.e., Cap 476: Marine Parks Ordinance). However, due to its small size (0.2 km^2) and close proximity to human activities in coastal areas, the conservation of this reserve may be jeopardized by anthropogenic impacts, such as partially-treated sewage discharges and contaminated surface runoff (Xu et al., 2015a).

Due to concerns about the adverse impacts of NP and BPA on aquatic organisms worldwide, the levels of these chemicals have been quantified in different riverine and estuarine environments (Naylor et al., 1992; Blackburnet et al., 1999; Isobe et al., 2001; Ferguson et al., 2001; Rice et al., 2003; Jonkers et al., 2003; Li

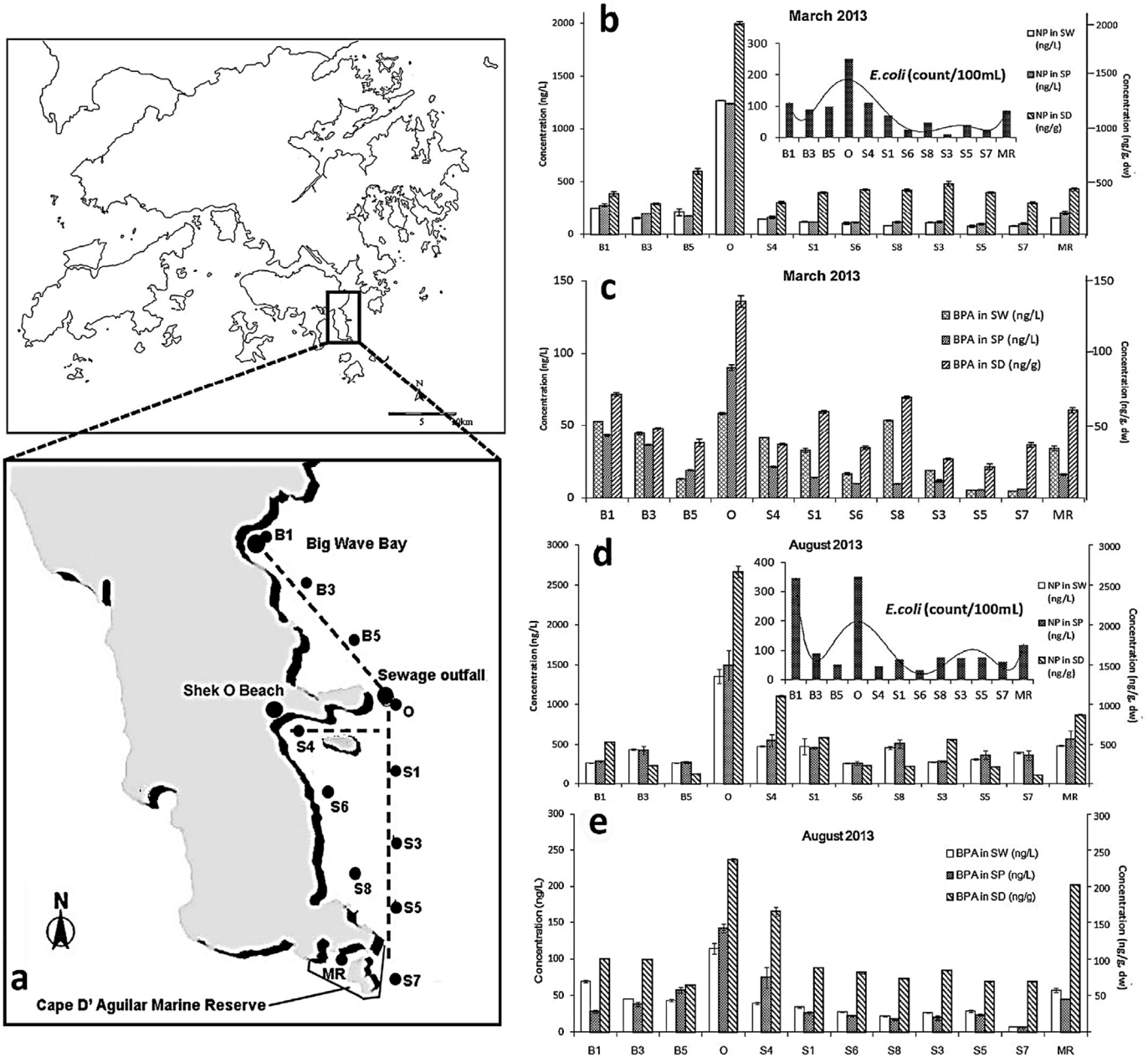

Fig. 1. Sampling locations along transects from Big Wave Bay, Shek O Sewage Treatment Plant and Shek O swimming beach to Cape D'Aguilar Marine Reserve (CAMR) in Hong Kong (a). Concentrations (mean ± SD, $n = 3$) of nonylphenols (NP) and bisphenol A (BPA) in seawater (SW), suspended particles (SP) and sediments (SD), and *E. coli* in seawater from Big Wave Bay to Shek O to the Cape D' Aguilar Marine Reserve (CAMR) in March 2013 (b and c) and August 2013 (d and e).